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THE EFFECT OF REMOVAL OF LIPIDS BY SOLVENT EXTRACTION ON THE FEEDING VALUE OF COTTONSEED AND SOYBEAN MEALS

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The practice of solvent extraction of cottonseed and soybean meals is becoming increasingly common because of the higher price of the oils in comparison with the meals and because of increased efficiency and safety of the methods. The question arises as to the relative value of the press and solvent extracted products as feeds. If the fat in cottonseed or soybean meals is of nutritional importance this fact must be considered when choosing between solvent and press extracted meals even though the amounts of meal in a mixed feed, or in the total daily ration, may be slight. This discussion includes a review of the literature on the functions of fat in the diet and a critical examination of how these functions may be affected by using solvent or press extracted cottonseed or soybean oil meals in rations.

It must be understood that the fat content is not the only factor affected by the solvent extraction of seed meals. The nutritive value of the protein may also change. The bulk of the evidence indicates no significant difference in the biological value of the proteins of solvent and press extracted soybean meals as measured by growth of cows (1), pigs (2, 3, 4) and chickens (5, 6, 7) or as measured by nitrogen and sulfur retention by rats (8) when the effect of heating is not a factor (9). It has been known for sometime that heating increases the biological value of soybean protein but that fat solvents have no effect (8). In experiments with pigs (4) there was evidence that the solvent process meal did produce faster gains than the expeller extracted meal, but it required more feed per weight of gain. Higher average nutritive value of solvent extracted soybean oilmeal than of expeller type has been reported for chickens (7).

Few studies have been made of the feeding advantages between solvent and press extracted cottonseed meals. Studies with range cattle were inconclusive (10).

Unpublished work at this Station (11) has shown a pronounced increase in feeding value of the proteins of an isopropyl alcohol extracted cottonseed meal over those of hydraulic extracted meals. Gossypol content was no factor.

A non-lipid factor which may be affected by the solvent extraction of cottonseed meal is the gossypol content. Hexane extraction leaves the active gossypol in the meal, requiring cooking to inactivate it. Isopropyl alcohol extraction, however, removes the gossypol with the lipids (12).

Assuming a possible important role for the fat of seed meals in the rations, the relative effect of substituting solvent extracted meals for press extracted meals may be determined by simple calculations. It may then be judged from the figures whether the relative effect is of any practical importance.

The fat content of press extracted meals is approximately 6 percent, while that of solvent extracted meals is something under 1 percent. With few exceptions the percentage of seed meals in commercial mixed feeds varies from 5 to 30 percent. By substituting the solvent extracted meal there is thus a decrease of from 0.25 to 1.5 grams of ether-extract per 100 grams of mixed feed. Since, further, the

ether-extract of mixed feeds may be expected to average about 3 percent (13), this loss of fat would amount to a reduction of from 8 to 50 percent in the fat content of mixed feeds. Looked at another way, the fat content of the mixed feeds would be reduced from 3 grams to between 1.50 and 2.75 grams per 100 grams of feed, depending upon whether the amount of meal used in the mixture was 30 or 5 percent respectively.

The most obvious effect of the loss of fat is in the energy value. The productive energy of press extracted soybean oilmeals having an average ether-extract content of 6.8 percent was found to be 79.7 therms per 100 pounds, while that of the solvent extracted meals of 0.7 percent average ether-extract contained 71.2 therms (14). This represents a difference of 10.6 percent in the energy value. From the productive energy values of cottonseed meals containing an average of 6.8 percent ether-extract, 72.5 therms per 100 pounds, and the productive energy coefficient of its ether-extract, 170 therms, the productive energy of 1 percent ether-extract cottonseed meal may be calculated to be 66.5 therms per 100 pounds, the difference between the low fat and high fat meals being 6.0 therms per 100 pounds, or 8.4 percent.

From the foregoing figures the differences in energy values of mixed rations containing press and solvent extracted soybean oil meals at levels of 5 and 30 percent is 0.5 and 3.5 percent respectively. The differences in energy values of mixed rations containing the low and high fat content cottonseed oil meals at 5 and 30 percent levels is 0.4 and 2.6 percent respectively.

Related to energy is the position of fat in the economy of food utilization. It has been shown in both rats (15) and swine (16) that increase in live weight per unit of feed consumed increased with increase in fat content of the ration. The increase in the energy value of the higher fat ration is insufficient to account for all the increase. In the case of rate, it has been shown (15) that this saving is due to decreasing heat from the catabolism of carbohydrate and from fat synthesis. These authors had previously shown (17) that fat decreased the energy expense of utilization of food protein and carbohydrate.

Besides energy, however, fat also is the source of the essential fatty acids (18). Very little is known of the requirements of domestic animals for essential fatty acids. If required at all, the amount must be small and easily supplied from other constituents of the mixed feed than the seed meal. Although the rat is the most susceptible animal studied, 23 milligrams per day appear to give good growth and reproduction (19) though 100 milligrams daily may be the optimum for lactation (20). The dearth of data on the need of domestic animals for essential fatty acids is due to the difficulty in excluding from the ration the small amounts the animals require.

A third function of fat in the diet is as a vehicle of the fat-soluble vitamins. Cottonseed oil and soybean oil each contain about 0.1 percent total tocopherols which may play a role in milk production (21). Also, fat in the diet may aid in the absorption of the fat-soluble vitamins and carotene from other food sources. This is especially true of carotene (22). However, rancid fat may destroy the fat-soluble vitamins before absorption, especially in the absence of antioxidant (23). Quantitative relationships are probably important here. The differences in the fat content of mixed feeds prepared with solvent as compared with press extracted meals cannot reasonably be considered as having any significant effect on the absorption or destruction of vitamins.

Fat is known to decrease the need of animals for thiamin since that vitamin is functional in the metabolism of carbohydrates (24). However, the small amount of

fat lost to the diet by using solvent extracted meal reduces this factor to insignificance.

It has been reported repeatedly that small amounts of fat in the diet aid calcium absorption (25) and calcification (26) by maintaining a favorable intestinal acidity. This effect is more noticeable in the rachitic animal and may be due to increased absorption of vitamin D with increase in fat (27).

A function often attributed to fat which could be of significance in small amounts is the added palatability it imparts to food through flavor and texture. Swine fed corn and minerals plus expeller and solvent extracted soybean meal free choice consumed 5 times more of the expeller than of the solvent extracted meal (4). There is experimental evidence with cattle indicating reduced palatability of solvent extracted meal which may be due to this factor (1).

A similar possible effect difficult to measure in animals, and of questionable significance if present, is the high satiety value fat is said to have in human dietaries (28).

Low blood fat values, decreased fat tolerance and increase in respiratory quotient have all been observed in low fat diets in both man and animals. The significance of these physiological changes, however, has never been determined in terms of health or of flesh production.

The observations that low fat diets had a deleterious effect on egg production (29, 30) were made on diets containing less than 1 percent of fat. Other workers observed no effect on production, fertility, hatchability or mortality of chicks when the diet contained between 1.56 and 3.12 percent of fat (31). Increase in the fat content of the diet from below 1 to 2.8 percent with corn oil did not affect production of eggs or size of yolk (32).

Since laying mashes ordinarily do not contain over 15 percent soybean or cottonseed oil meal, substituting the solvent extracted for the press extracted meal would produce a maximum reduction of the fat content from about 3.5 to 2.5 percent, a difference of only about 0.5 percent. In the light of the evidence just reviewed there should thus be no concern felt for the effect on egg production of solvent extracted meal in egg mashes as a result of its decreased fat content.

The comparison of solvent and press-extracted soybean oil meal on milk production has been made experimentally as part of a broad program on the effect of dietary fat on lactation (33, 34). Substituting solvent extracted soybean meal for ground soybeans reduced the ether-extract of the ration from 6.27 to 3.35 percent and from 6.33 to 3.09 percent in two tests respectively. The results showed an advantage for the higher fat ration in the amount of 4 percent fat converted milk produced, the increases being attributed to a higher fat content (35). Further work by the authors makes it appear that the fat effect may be an energy one(36, 37). Roughage may partially compensate for low fat in the diet but not for high producers as the roughage intake is limited. It was pointed out that solvent extracted meals may be used with excellent results in dairy rations if other ingredients of high fat content are also used.

Others, however, in testing the effect of substituting solvent extracted for press extracted soybean oil meal in dairy rations, were unable to find significant differences in milk production by increasing the fat content of the ration from 2.69 to 4.89 percent (38), or from 1.3 to 4.75 percent (39). The New York group criticizes these experiments on the basis of inadequate control (36).

It must be pointed out, however, that it may not be fat per se that appears to be the factor but some constituent of the fat. Thus a "fat soluble lactation factor" has been reported in unsaponifiable fractions of the seeds of Trigonella foenum graecum (40), and Crisco and lard were found to promote lactation better than corn oil (41). Additions of hydrogenated coconut oil and ethyl linolate were found to have no advantage over a fat-free diet, but corn oil produced a very significant response (42). It has been reported recently that tocopherols increase milk fat concentration in dairy cows as well as the total "4 percent milk" (21). Since it is in dairy rations that soybean and cottonseed meals are used in highest percentage content (except for cattle and swine supplements or concentrates), the final answer to this problem of the effect of fat on milk production is of practical importance.

It was just shown that by substituting solvent extracted meal containing 1 percent ether-extract for press extracted meal containing 6 percent in rations containing 30 percent seed meal, the total fat content of the ration may be reduced to 1.5 percent. Until it is definitely shown otherwise, the evidence indicates a decreased milk yield on such a low fat ration.

The effect of fat in the diet on the composition of body and milk fat has been the object of experimentation for many years. It is questionable, however, if the conclusions have any weight in our present problem since, to be measurable, the amounts of fat in the diet must be greater than the differences being considered here, and at a much higher level in the diet (23, 43).

The inclusion of some fat in the diet appears to have some effect on growth. Calves raised on skim milk gained 1.07 pounds per day in contrast with a gain of 1.43 pounds on whole milk (44), and "rats showed suboptimum growth on diets containing only the fat in crude casein, yeast and 2 or 3 drops of cod liver oil per day" (23).

The role of fat in storage is an ever present problem in commercial feeds. Ordinarily it is considered that fat causes increased storage problems due to possibilities of rancidity. It has been shown (45), however, that during storage for 1, 3 and 6 months at 30° and 76° F, the presence of fat in soybean meal has a protective effect on the proteins as measured by the percentage of true proteins, sodium chloride soluble protein and digestibility in vitro by proteolytic enzymes. In the case of corn these protein changes have been correlated with loss of feeding value (46).

The present discussion has brought out that fat extraction has no effect on the biological value of the proteins or on egg production. Considered individually the loss of essential fatty acids, reduced need for thiamin, effects on calcium metabolism, satiety value, decreased fat tolerance and effect on growth may be ignored in considering the relative feeding value of solvent and press extracted meals.

Some effects were shown to be two-edged, thus in storage the fat may become rancid or it may prevent loss in biological value of the protein, and the tocopherol may act as antioxidant.

In general, however, the conclusion (23) that "nearly all experiments have shown that the inclusion of fresh palatable and digestible natural fats improves the diet in some way" is inescapable. Not only does fat have functions per se, such as energy value and possibly lactation and growth, but it aids other dietary factors in the performance of their functions. In many cases, the substitution in the ration of solvent extracted soybean or cottonseed meals for the press extracted meals reduces the total fat intake sufficiently to have measurable effects unless other sources of fat are substituted.

Bibliography

1. Rusk, H. P. and Snapp, R. R. Old and new process soybean oil meals compared as feed. Ill. Sta. Rpt. 1937, p. 88.

2. Robinson, W. L. Toasted solvent soybean oil meal for pigs. Ohio Agri. Expt. Sta. Bul. 592, 1938, p. 95.

3. Robinson, W. L. Soybean oil meal for pigs. Ohio Sta. Bimo. Bul. 209 (1941) p. 56.

4. Vestal, C. M. and Shrewsbury, C. L. A study of the relative value of expeller process and solvent process soybean oil meal. Ind. Sta. Rpt. 1937.

5. Bird, H. R. and Burkhardt, G. J. Factors affecting the nutritive value of soybean oil meals and soybeans for chickens. Maryland Sta. Bul. A27 (1943).

6. Bethke, R. M. and Sweet, M. C. The comparative value of expeller and toasted solvent soybean oil meal for chicks. Ohio Sta. Bimo. Bul. 199 (1939) p. 122.

7. Draper, C. I. and Evans, R. J. Plant protein concentrates in the chick ration. Poultry Sci. 23, 507 (1943).

8. Johnson, L. M., Parsons, H. T. and Steenbach, H. Effect of heat and solvents on nutritive value of soybean protein. J. Nut. 18, 423, (1939).

9. Hayward, J. W. The nutritive value of soybean oil meal prepared by different methods of oil extraction. Oil and Soap 14, 317 (1937).

10. Savage, D. A. and McIlvain, E. H., Eleventh Semi-ammual Report, Forage Division, Bureau of Plant Industry, U. S. Southern Great Plains Field Station, Woodward, Oklahoma.

11. Unpublished research, Hale, Fred, Lyman, C. M., Texas Agricultural Experiment Station.

12. Harris, W. D., Bishop, F. F., Lyman, C. M., and Helpert, R. Report on isopropanol as a solvent for extraction of cottonseed. In press. J. Am. Oil Chem. Soc.

13. Brock, F. D. and Holleman, M. P. Commercial Feeding Stuffs. Texas Agri. Expt. Sta. Bul. 681, Sept. 1946, p. 11.

14. Fraps, G. S. Texas Agri. Exp. Sta. Bul. 461, revised 1947.

15. Forbes, E. B., Swift, R. W., Elliott, R. F. and James, W. H. Relation of fat to economy of food utilization. I. By the growing albino rat. II. By the mature albino rat. J. Nut. 31, 203, 213 (1946).

16. Robinson, W. L. Fat in rations for swine. Ohio Agri. Expt. Sta. Bimo. Bul. 224, Sept. 1943, p. 203.

17. Forbes, E. B. and Swift, R. W. Associative dynamic effects of protein, carbohydrate and fat. J. Nut. 27, 453 (1944).

18. Burr, Geo. O. Significance of essential amino acids. Federation Proceedings of Federation of American Societies of Expt. Biol. 1, 224 (1942).

19. MacKenzie, C. S., MacKenzie, J. B. and McCallum, E. V. Growth and reproduction on a low fat diet. Biochem. J. 33, 935 (1939).

20. Quackenbush, F. W., Kummerow, F. A. and Steenback, H. The effectiveness of linoleic, archidmic and linolenic acids in reproduction and lactation. Dept. Biochem. College of Agri. W. Wisc. Madison.

21. Harris, P. L., Swanson, W. J., and Hickman, K. C. D. Covitamin studies. VI. Effect of tocopherol supplementation on the output of vitamin A, carotene and fat by dairy cows. J. Nut. 33, 411 (1947).

22. Muelder, Kathleen D. and Kelly, Eunice. The effect of the level of fat in the diet upon the utilization of vitamin A. J. Nut. 23, 335, (1942).

23. Burr, Geo. O. and Barnes, H. R. Non caloric functions of dietary fats. Phy. Rev. 23, 264 (1943).

24. Cowgill, A. R. The vitamins. Amer. Med. Assoc. Chicago, 1939.

25. Boyd, O. F. and Crum, C. L. and Lynn, H. The absorption of calcium soaps and the relation of dietary fat to calcium utilization in the white rat. J. Biochem. 95. 29 (1932).

26. Jones, J. H. The relation of the pH of intestinal contents to calcium and phosphorus utilization. J. Biol, Chem. 142, 557 (1942).

27. Booth, R. G., Henry, K. M. and Kon, S. K. A study of the antirachetic effect of fat on rats receiving high calcium-low phosphorus rachitogenic diets. Biochem. J. 36, 445 (1942).

28. Anderson, W. E. and Williams, H. H. The fate of fat in the diet. Phy. Rev. 17, 335, (1937).

29. Davis, H. J. and Upp, C. W. Studies on the fat requirement of the domestic fowl. Abst. of papers presented at 33 Annl. meeting on Aug. 12-15 (1941) J. Poult. Sci. 20, 459 (1941).

30. Russell, W. C., Taylor, M. Wight and Walker, H. A. The intake and output of fat by the hen on low fat and normal ration. J. Poultry Sci. 20, 377 (1941).

31. Heywang, B. W. and Titus, H. W. Weight and quality of the yolk of eggs of chickens fed diets containing vegetable oils. J. Poultry Sci, 20, 483 (1941).

32. Heywang, Burt W. Some results of feeding diets of varying fat content to laying pullets. Poultry Sci. 22, 446 (1943).

33. Maynard, L. A., Loosli, J. K., McCoy, C. M. Influence of different levels of fat intake upon milk secretion. N. Y. (Cornell) Agr. Exp. Sta. Bul. 753, 3 (1941).

34. Lucas, H. L., Loosli, J. K. and Maynard, L. A. A study of the effect of dietary fat and fat soluble vitamins upon milk and fat secretion. Cornell U. Agri. Expt. Sta. Memoirs 251, 1943.

35. Maynard, L. A., Garner, K. E. and Hardin, A. Soybeans as a source of fat in the dairy ration. Cornell Agri. Expt. Sta. Bul. 722, (1939).

36. Loosli, J. K., Maynard, L. A. and Lucas, H. L. Further studies of the influence of different levels of fat intake on milk secretion. Cornell U. Agr. Expt. Sta. Memoirs 265, Oct. 1944.

37. Loosli, J. K. and Maynard, L. A. High fat dairy rations give higher milk production. Farm Res. (New York State and Cornell Stations). 11, 3 (1945). Expt. Sta. Record 94, 516 (1946).

38. Monroe, C. F. and Krauss, W. E. Relationship between fat content of dairy grain mixtures and milk and butterfat production. Ohio Agri. Expt. Sta. Bul. 644 (1943).

39. Schubert, A. R. and Wells, J. G. Effect of replacing solvent extracted soybean oil meal with soybeans in a low-fat ration. Mich. Agr. Expt. Sta. Quart. Bul. 23, 72 (1940).

40. El Ridi, M. S. and Shabat, M. A preliminary note on a fat-soluble lactation factor. J. Roy. Egypt Med. Asso. 27, 199 (1944).

41. Vinson, L. J., Cerecedo, L. R. Growth, reproduction and lactation in rats maintained thru 4 generations on highly purified diets. Arch. Biochem. 3, 389 (1944).

42. Loosli, J. K., Lingenfelder, J. F., Thomas, J. Wm. and Maynard, L. A. The role of dietary fat and linoleic acid in the lactation of the rat. J. Nut. 28, 81 (1944).

43. Hilditch, T. P. The chemical constitution of natural fats. John Wiley and Sons, New York (1940).

44. Gulleckson, T. W., Fontaine, F. C. and Fitch, J. B. Various oils and fats as substitutes for butter fat in the ration of young calves. J. Dairy Sci. 25, 117 (1942).

45. Jones, D. B. and Gersdorff, C. E. F. Changes that occur in the proteins of soybean meal as a result of storage. J. Am. Chem. Soc. 60, 723 (1938).

46. Jones, D. B., Devine, J. P. and Gersdorff, C. E. F. Effect of storage of corn on the chemical properties of its proteins and on its growth promotive value. Cereal Chem. 19, 819 (1942).

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